APPENDIX C - SOILS

Introduction

The following Appendix contains five separate soils documents, five maps, and eight tables: The soil documents include: 1) Soil Transect Methods; 2) Tri-Forest Monitoring Review – Summit Fire Recovery Project; 3) Effects of a Feller-Buncher Operation on Soil Bulk Density; 4) Overland Transport Distances of Sediment From Roads, Swamp Planning Area (Draft); and 5) Sediment Export From Logging Units During Summit Fire Salvage (Draft).

The five maps include:
1) Alternative 2 Tractor Units and BAER Burn Severity
2) Alternative 3 Tractor Units and BAER Burn Severity
3) Alternative 4 Tractor Units and BAER Burn Severity
4) Alternative 5 Grapple Pile Units and BAER Burn Severity
5) Perennial and Intermittent Streams, and Ephemeral Draws (labeled).

The eight tables include:
1) Easy Fire – Proposed Harvest Units & BAER Burn Severity, Alternative 2, Tractor Units
2) Easy Fire – Proposed Harvest Units & BAER Burn Severity, Alternative 2, Skyline & Helicopter Units
3) Easy Fire – Proposed Harvest Units & BAER Burn Severity, Alternative 3 - Tractor Units
4) Easy Fire – Proposed Harvest Units & BAER Burn Severity, Alternative 3 - Skyline & Helicopter Units
5) Easy Fire – Proposed Harvest Units & BAER Burn Severity, Alternative 4 - Tractor Units;
6) Easy Fire – Proposed Harvest Units & BAER Burn Severity, Alternative 4 - Skyline & Helicopter Units
7) Easy Fire – Proposed Fuels Treatment & BAER Burn Severity, Alternative 5 - Grapple Pile Units
8) Easy Fire – Fuels Treatment & BAER Burn Severity, Alternative 5 - Hand Felling, Piling & Burning Units.

1. Soil Transect Methods

Categorize the soil conditions using the *Soil Class Disturbance Definitions* and the *Soil Assessment Data Forms*. When calculating the percentage of an activity area that contains detrimental soil conditions, use the percentage of points designated as Class 2 and Class 3. Do not sample non-forest inclusions. The following method was used:

Transects: Find a “no impact” area to calibrate your foot/sharpshooter. Also, find an obvious skid trail or landing to get a feel for detrimental compaction. Use a minimum of 1 transect across a representative section of the unit (this is not a statistical sample). From the beginning of the transect walk in a straight line sampling every 4-5 feet (1 pace). The line can be bent, to ensure the area crossed is representative. Collect a minimum of 200 points along each transect. Record soil impacts at each sampling point based on *Soil Class Disturbance Definition*.

Description of Detrimental Soil Conditions[1]

These descriptions are found in Forest Service Manual 2500 - Watershed and Air Management R-6 Supplement 2500-98-1.

Detrimental Compaction - An increase in soil bulk density of 20 percent, or more, over the undisturbed level for volcanic ash soils. For all other soils, it is an increase in soil bulk density of 15 percent, or more, over the undisturbed level, a macropore space reduction of 50 percent or more, and/or a reduction below 15 percent macro porosity. Assess changes in compaction by sampling bulk density, macro porosity, or penetration resistance in the zone in which change is relatively long term and that is the principal root development zone. This zone is commonly between 4 to 12 inches in depth.

Detrimental Displacement - The removal of more than 50 percent of the A horizon from an area greater than 100 square feet, which is at least 5 feet in width.

Detrimental Puddling - When the depth of ruts or imprints is six inches or more. Soil deformation and loss of structure are observable and usually bulk density is increased.

Detrimental Surface Erosion - Visual evidence of surface loss in areas greater than 100 square feet, rills or gullies and/or water quality degradation from sediment or nutrient enrichment.

Detrimental Burned Soil - When the mineral soil surface has been significantly changed in color, oxidized to a reddish color, and the next one-half inch blackened from organic matter charring by heat conducted through the top layer. The detrimentally burned soil standard applies to an area greater than 100 square feet, which is at least five feet in width.

Soil Disturbance Class Definitions

<table>
<tr>
<td>
<u>Class 0: Undisturbed Natural State</u>

Soil surface:

No evidence of past equipment operation.
No depressions or wheel tracks evident.
Litter and duff layers present and intact.
No soil displacement evident.

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<u>Class 1: Low Soil Disturbance</u>

Soil surface:

Faint wheel tracks or slight depressions evident (e.g. <2” deep).
Litter and duff layers usually present and intact.
Surface soil has not been displaced.
Some evidence of burning impacts including a mosaic of charred and intact duff layer to partially consumed duff layer with blackened surface soil.

Soil resistance to penetration with tile spade or probe:

Resistance of surface soils may be slightly greater than observed under natural conditions. Concentrated in top 0-4 inch depth.

Observations of soil physical conditions:

Change in soil structure from crumb or granular structure to massive or platy structure, restricted to the surface 0-4 inches.

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<u>Class 2: Moderate Disturbance</u>

Soil surface:

Wheel tracks or depressions evident (e.g. 2-6” deep).
Surface soil partially intact with minimal displacement (area must meet the size requirement).
Burning consumed duff layer, root crowns, and surface roots of grasses. Surface soil is blackened.

Soil resistance to penetration with tile spade or probe:

Increased resistance is present throughout top 4-12 inches of soil.

Observations of soil physical conditions:

Change in soil structure from crumb or granular structure to massive or platy structure, restricted to the surface 4-12 inches.
Platy structure is generally continuous and holds together when shaken.
Large roots may penetrate the platy structure, but fine and medium roots may not.

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<u>Class 3: High Disturbance</u>

Soil surface:

Wheel tracks or depressions highly evident (e.g. >6” deep). .
Evidence of topsoil removal, gouging and piling.
Soil displacement has removed the majority of the surface soil. Subsoil partially or totally exposed.
Burning consumed duff layer, root crowns and surface roots of grasses. Evidence of severely burned soils (mineral surface soil red in color) in an area that meets the size requirement.

Soil resistance to penetration with tile spade or probe:

Increased resistance is deep into the soil profile (>12 inches).

Observations of soil physical conditions:

Change in soil structure from granular structure to massive or platy structure extends beyond the top 12 inches of soil.
Platy structure is continuous.
Roots do not penetrate the platy structure.

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Soil Assessment Data Form

Unit: Date:
Who:
(Form date: 10-19-02)
Approximate years since latest skidding: % in roads & landings?
(previous sale & unit?)

Where are transects? (describe or sketch map)

0	1	2	3

Number of previous entries: How much machine piling?
Skid trail spacing:

Any off-skid-trail disturbance visible? Can & should existing skid trails be reused? If not, why not?

What are "2" & "3" due to: displacement, compaction? How much displacement?

Note conditions that may call for special mitigations: steep slopes, scab inclusions, ephemeral "streams", draws, moist soil (put on map if possible)

Soil Assessment Data Form – page 2

General range of soil characteristics:

Slope %	Shovel penetration depth	Coarse fragment abundance & size, texture How much ash?

Suitability of the soil for subsoiling in terms of depth, stoniness, and slope:

Is one part of unit hit harder than others?

Do these transects appear representative of other parts of unit?

General Notes:

2. Tri-Forest Monitoring Review – Summit Fire Recovery Project

File Code: 1920 **Date:** December 21, 2001

Subject: Tri-Forest Monitoring Review – Summit Fire Recovery Project

To: District Ranger, Blue Mountain Ranger District

Thank you for hosting a Tri-Forest Monitoring Team visit to your District. This document summarizes the findings of the review of the Summit Fire Recovery Project conducted on October 2 and 3, 2001. Please contact Tim Davis if you have any questions or would like copies of the individual team member reports.

The Monitoring Team consisted of:

Craig Busskohl	Soil Scientist	Umatilla SO
Del Groat	Fisheries Biologist	Pomeroy RD, UMA
David Hatfield	Acting Planning Staff	Umatilla SO
Mike Piazza	Sale Administrator	Wallowa Valley RD, WAW
Tim Davis	Monitoring Coordinator	Blue Mountains Zone

District employees:

Bruce Carey	Sale Administrator
Mary Lou Welby	Hydrologist (October 2 office meeting)
Hersh McNeil	Soil Scientist (October 3)

Introduction

Tri-Forest monitoring field reviews have been implemented four of the last five years in an effort to improve consistency and provide an avenue for information sharing across the Forests. This year's review emphasis was the effects of project implementation on the soils resource. Part of the rational for choosing soils as the focal point for the reviews was the inclusion of soils as an issue in a number of recent appeals and litigations. There has been a perception that the effects of project implementation on soils has been inadequately analyzed and documented. Another reason for choosing soils was to facilitate discussions which might lead to increased consistency within the Blue Mountains in the determination of existing soils conditions, and the analysis of effects.

The Summit Fire Recovery Project Record of Decision was signed on July 13, 1998. This project responded to conditions created by the Summit Fire which burned 37,961 acres in August and September of 1996. Post-fire review identified a specific restoration need of moving the area closer to its historic range of stand structure (in terms of fuel loadings, vegetation, and fish and wildlife habitat). There was also a need to provide economic benefits to the local community. Activities included in the decision were fuel reduction, road closures and decommissioning, reforestation, rehabilitation of watershed problems, riparian planting, and noxious weed control.

At the District's request the Monitoring Team focused on salvage sale activity associated with the Summit Project. These activities generated controversy and were the subject of much review prior to and after their implementation. The District was interested in the Monitoring Team's impressions of these activities and the effects on the soils resource. Approximately 6,700 acres of salvage activity were implemented via a group of salvage sales between July 1998 and April 1999. The Team visited a small sample of these 6,700 acres, primarily looking at sites where ground conditions or harvest system corresponded to conditions which had the "worst case" potential for adverse effects on soils.

An important soil consideration in the project area is the presence of Clarno formation and the residual clayey soils that develop from that formation. As opposed to the ash surface soil which is also present in the area, the clayey soils present important management considerations related to the timing and application of harvest systems.

Review Sites

<u>Roadside Hazard Tree Removal</u>

Background: The safety issue related to roadside hazard trees located within riparian areas was dealt with by felling these trees. Some hazard trees located within the PACFISH buffer were removed.

Findings:

- None of the hazard trees which were removed were in position to provide shade to the stream.
- Trees were felled toward the stream where possible and left on site as large woody debris.
- Tree planting projects had occurred in the riparian area.

Beaver 512

Background: The part of the unit reviewed was generally flat and near the 300-foot buffer on Beaver Creek. Primarily commercial thin sized material was removed from this unit by processors and skidders taking whole trees to the landing areas. Skid trail spacing was about 120 feet.

Findings:

- No rutting from salvage operations or evidence of sediment movement.
- Considerable cover of exotic grasses.
- Skid trails well vegetated and difficult to see.
- Old road into unit closed and stable, but no drainage or closure measures evident.

Myrt 52

Background: This unit is part of the monitoring program designed to monitor sediment movement on uplands to help determine if logging after wildfire is consistent with maintaining water quality. The unit is relatively flat. It was logged in November. The larger trees were felled by hand and skidded to the landing area. In the second harvest phase, a feller-buncher removed the smaller trees. Skid trail spacing was about 100 to 120 feet.

Findings:

- Generally it was difficult to see the skid trails.
- No sign of soil movement.
- Some rutting around the landing area, probably due to operations in marginal soil conditions.
- Native surface access road was closed and waterbarred. Waterbars were working as designed. This road could be considered for decommissioning.

Badger Creek Bridge

Background: A thunderstorm event in the summer of 1998 created flood conditions which led to large amounts of material coming from the uplands and being channeled through the system. Forest Road 4550 was damaged during the event and the culvert at this location failed. It was replaced with the current temporary bridge. At time of the event no salvage activity had occurred.

Findings:

- Post-fire management activities were not a factor in creating the event or the resultant effects.
- The road crossing may have exacerbated the conditions but was an existing facility. Replacing the culvert with the temporary bridge did not affect the site conditions.
- Large woody debris recruitment as a result of the event is a benefit to fisheries in the long-term.
- Riparian recovery in the area is evident, with revegetation of native grasses and shrubs.

Badger 28

Background: Unit logged by ground based system operating in November. Conditions became too wet and operations were shut down.

Findings:

- Unit had the most disturbance of any unit the team visited. Disturbance concentrated near landing.

- Near upper end of guidelines for detrimental soil conditions, but still within the guidelines. Detrimental conditions higher than achievable with this logging system under more favorable conditions.
- Some rutting and soil exposure occurred before operations were shut down.
- No evidence of soil movement.
- Subsoiling not prescribed for this unit but would be a candidate (deep soil, few coarse fragments).

Myrt 5

Background: The harvest system originally planned for the reviewed portion of this unit was uphill skyline to an access road (0.2 miles), which would need to be constructed. To avoid building the road, the system was changed to ground based, using FMC skidders. Skid trail spacing was about 70 to 100 feet. Slope was 30 to 40%. Unit was logged under dry conditions.

Findings:

- Some rutting on trails. Displacement due to "dry dusting" of powdery ash soil as well as skidder use on steep slope.
- Overall disturbance and erosion hazard within the unit increased as opposed to the cable yarding harvest system. Trade-off between these results and effects of building the temporary access road.
- No erosion evident.
- Waterbars on trails functioning as designed. Spacing of waterbars greater than what normally would be prescribed for these slopes and conditions.
- The lower access road (539 road) in the unit, while closed, is a candidate for decommissioning or obliteration. Currently this road had inadequate drainage and is producing some sediment, which has the potential to reach the stream below. At the time of the review it was not evident if sediment had reached the stream.

Wide 317

Background: A small portion of this unit is an area where water collects and remains into the summer. It has possibly become "wetter" since the fire as the trees were all killed and are no longer transpiring water out of the area. General agreement among the team was that this area would not be considered a wetland. A nearby small wetland below the unit was identified during unit layout and was left out of the unit, and was unaffected by the harvest activity. The wet site conditions in the area within the unit were not noted during unit layout and not noticeable during logging since operations were conducted over snow. Mechanical tree felling equipment operated during too wet conditions and broke through the snow in this area before operations were shut down. The unit was tractor logged.

Findings:

- Deep ruts were created when equipment broke through the snow.
- No erosion evident.

- This operation exemplifies the care needed in logging under winter conditions. When conditions are transitional, monitoring on a frequent basis is needed.
- District may need a better identification process for wetlands and wet areas, especially when dealing with changing conditions after severe fire.

Deep 307

Background: Team looked at an existing native surface access road used during the ground based harvest on Deep 307. The first section of this road slopes down toward the main road, slopes are from 5 to 10%. There is deep ash soil in this area and soil had been displaced, eroded, and "dry dusted" out of the road prism over decades, resulting in a down cut situation. The road is closed with a dirt berm, but unauthorized traffic is bypassing the berm. This traffic is destroying the waterbars established after the harvest operations.

Findings:

- Difficult to get adequate drainage where road is down cut.
- Waterbars are ineffective due to powdery soil conditions and damage from unauthorized traffic.
- Some sediment has moved off the road but has dropped out prior to reaching a nearby class 4 stream channel.
- Road condition is the result of past use, not only the recent salvage logging.
- Road is a candidate for obliteration or heavy reworking.
- A nearby access road to a helicopter unit was reviewed. This road crosses a class 4 channel but the crossing is well armored and did not rut. Probably little if any sediment was generated at this location by the use of this road.

Road Comments

Background: The observed portion of the project area is highly roaded. One reviewer noted more roads in the area visited than they had ever observed. Many of these roads are non-system, old logging roads. Some of the roads which would be considered closed or "decommissioned" could still be traveled, particularly by OHV operators. Use of system roads for timber haul during wet conditions can be a source of sediment.

Findings:

- Many of the closed non-system roads still function as a road in a hydrological sense, concentrating water flow and possibly contributing sediment in small amounts.
- An active road decommissioning or obliteration policy for the non-system and un-needed system roads is recommended. The Forest's road analysis should cover the analysis and decision processes required.
- While in one case (near the junction of roads 4550 and 749) there was evidence of sediment movement associated with wet condition haul (sediment dropped out at a culvert outflow over 750 feet from the nearest draw), in general haul was suspended by sale administrators when warranted by conditions.

- Travel needs to be more effectively blocked on some closed and decommissioned roads to attain objectives, such as vegetative and ground cover recovery.

Skyline Operations

The Team did not specifically review any skyline units. The sale administrators felt the skyline operations and mitigations (waterbars, log barriers, or slash for erosion control on yarding corridors) were successfully implemented. A cursory review of several skyline units while driving past revealed no observed erosion effects.

Overall Project Conclusions

- Soil impacts are consistent with Forest Plan guidelines for detrimental soil impacts on examined areas. There were a few problem areas, mainly associated with changing conditions and sale administrators getting overextended by multiple operations, but no extensive or consistent problems.
- Project design, layout, and implementation met stated project soil objectives.
- Great care was taken in upland harvest units to reduce erosion potential.
- Designated skid trail spacing and limiting off-trail use to feller-bunchers was successful at limiting detrimental soil impacts. Other BMPs for erosion control and limiting soil impacts worked well.
- There was a good working relationship between resource specialists and personnel implementing the projects.
- There was good continuity between the timber sale contracts and the Record of Decision. Very good follow through on mitigations, and the contract had the necessary provisions to address soil concerns.
- More thorough field determinations, such as stream classification and location of wet areas, could have prevented some undesirable results.
- One of the overall project objectives was to reduce fuel loads to reduce the risk of a future severe reburn. There was a question if this objective was met considering the number of snags left in some harvest units.

Recommendations

Continue using Forest Plan standards and guidelines related to soil.
Continue using Best Management Practices (BMPs).
Closed roads if not to be reused, maintained, or kept on the system should be considered for decommissioning or obliteration. Consider these restoration activities in assessments of overall watershed condition.
Areas with deep soil and few coarse fragments are good candidates for subsoiling when conditions warrant.
Expanded use of native seed where seeding is implemented will help with restoration of native grasses and forbs.

Care and frequent monitoring of conditions are necessary when logging under winter conditions, especially when conditions are transitional. Soils often do not freeze sufficiently to support machinery, or snow may not be deep and/or dry enough to provide support.

Closing

On behalf of the Monitoring Team I would like to thank the Blue Mountain Ranger District for taking the time to prepare for and participate in the review. We especially thank Bruce Carey for his expertise and willingness to have some of his sales reviewed. It is commendable that the Team was shown the problem units.

TIM DAVIS
Tri-Forest Monitoring Coordinator

Cc:

MAL FLT
UMA FLT
WAW FLT
Monitoring Team Members

3. Effects of a Feller-Buncher Operation on Soil Bulk Density

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2-13-96

Summary

A feller-buncher tracked 11% of a logging unit while removing 61 trees per acre (5.4 mmbf/ac). Of the 11% tracked, 15% was compacted by the feller-buncher, for a total increase in compaction due to the feller-buncher of less than 2% of the unit. The site was a ponderosa pine forest with loamy soils and was harvested when dry or only slightly moist. Compaction due to the feller-buncher is in addition to 4% of the area compacted due to skidding on skidtrails spaced 120 feet apart. It is also in addition to 11.5% compacted from previous entries and 7.5% compacted by natural processes.

Introduction

For a few years, loggers on Malheur National Forest have been using feller-bunchers to cut logs and transport them to skidtrails. Soils specialists and others have been concerned that feller-bunchers will increase violations of soil compaction standards, because feller-bunchers are not restricted to skid trails. For instance, skidders and feller-bunchers impacted 54% of the land on an operation on the Wallowa-Whitman National Forest (Zaborski 1989). In this paper, I report effects of a feller-buncher operation on soil density. Miscellaneous observations are reported in the Appendix.

Methods

Site

The study site is on Malheur N.F., Burns R.D., Calamity Timber Sale, unit 3, in T19S, R32E, sec. 14. Two blocks were selected for sampling. Blocks were rectangles fitted within the unit so they would have fairly uniform soil, vegetation, and topography. Locations of the blocks were randomly selected. The north block is 20 acres and the south block is 10 acres. Blocks are similar to each other, though the north block had more Idaho fescue than the south block.

Vegetation is Ponderosa pine/elk sedge (Johnson & Clausnitzer 1992). Soil parent material is derived from andesite and basalt. Texture of the top 6+ inches is loam. In the 4 to 6 inch depth, gravel was 10% by volume. Coarse fragments increased with depth. Slopes face west, at 15 to 35 %. Elevation is 5600 feet. Average annual precipitation is about 18 inches (Carlson 1974). Snow normally blankets the ground all winter, so freeze-thaw loosening of compaction is probably minor.

Past logging

Age of stumps and increases in tree growth indicate the sampled blocks were logged two or three times previously. Several trees were released about 1960-63 by the removal of large pine, perhaps in the Jackknife Salvage Sale. There are more stumps in the north block than in the south block from this logging. Common practice at that time was to machine pile and burn slash accumulations. In the north block, there may have been another release about 1969, although I have not found records of a timber sale at that time. The area was also logged under the Mountain Spring Sale, sold in 1985. During this sale, trees over 18 inches were removed from the north block, whereas the south block had a lighter individual tree mark. I found no increased growth after the Mountain Spring sale. Much of the slash from the Mountain Spring sale was not treated. These previous entries left about 19 stumps per acre.

Feller-buncher logging

The Calamity sale removed 61 trees per acre, containing 5.4 thousand board feet per acre, and left 32 trees per acre.

The feller-buncher moved within 0 to 10 feet of each tree to be cut, cut the tree, carried it back to the skid trail, laid it in a bunch in the skid trail, and moved to the next tree. The feller-buncher was a Timbco T435 HydroBuncher. It weighed about 52000 pounds, with 7.9 pounds per square inch average ground pressure when unloaded, static, and level. Grousers covered about 10% of the track and they were 3 inches long. The feller-buncher had a 40 foot arm, and the cab and arm could rotate as far as desired. The cab was self-leveling, and the feller-buncher had no troble handling the 15-35% slopes in this unit. Skidding was done by a rubber-tired skidder on most of the north block, and by a tracked skidder on the south block. Skid-trails were about 120 feet apart. Skid-trail locations were selected by the feller-buncher operator. Trees were de-limbed at the landing.

Logging occurred beween late October and mid December 1992. When the feller-buncher logged the north block, the ground was powder dry within 1/4 inch of the surface; by the time the south block was logged a week later, rains had moistened the soil to about 3 inches. Most of the north block was skidded under these dry to somewhat moist conditions. The south block was skidded several weeks later when more than 8 inches of snow was on the ground, and the ground was moist to 9 inches deep.

Soil sampling

The 'before' bulk density and disturbance classes were estimated according to Region 6 guidelines (Hazard & Geist 1984). The south block was sampled in July 1990 and the north block was sampled in June 1991. Bulk density was determined by the core method, using cores 1.0 inch long and 1.9 inches in diameter. Samples were taken from the 4 to 6 inch depth. 31 transects with 10 samples per transects were used in both blocks. Additional samples were taken to estimate bulk density of soil that was apparently undisturbed, giving a total of 80 undisturbed samples. Because it was difficult to see where previous compaction had taken place, most 'undisturbed' samples were taken between two trees that were too close to permit tractor passage. This procedure may bias the estimate of undisturbed soil density, because soil between two trees may not have the same density as other soil.

The 'after' sampling was done differently, in order to reduce cost. The 'after' disturbance classes were estimated on the same transects as the 'before' sampling. Disturbance classes were 'non-tracked', 'feller-buncher', 'edge of skid trail', and 'skid trails'. The 'non-tracked' class included the area between the two tracks of the feller-buncher. Disturbance classes were observed in early May, 1993. Grouser marks made the feller-buncher tracks clear at that time; on only one part of one transect was it difficult to determine if and where the feller-buncher had tracked the ground. 'Edge of skid trail' denotes the disturbed areas on both sides of skid-trails that had not been clearly tracked. Most disturbance in the 'edge of skidtrail' area was due to brushing of tree tops along the ground, rather than to traffic.

Bulk density sampling was done using paired samples to compare 'non-tracked' with 'feller-buncher'. 'Feller-buncher' samples were taken as near as possible to the start of a transect, and the paired 'non-tracked' sample was taken as near as possible to its paired 'feller-buncher'sample, considering that it had to be on the transect and 12 to 18 inches from a track. (Flock (1988) found that samples taken 2 feet outside tracks had the same bulk density as samples taken further away.) 'Edge of skid-trail' samples were taken the same way. Fourty-four 'feller-buncher' pairs were taken and 18 'edge of skid trail' pairs were taken, each pair on a different transect. Sampling was done in May and July, 1993.

<u>Statistics</u>

The effect of the feller-buncher on soil density can be described by the equation

f = n + e + ef

where f is the measured bulk density of the 'feller-buncher' samples.
n is the measured bulk density of the paired 'non-tracked' samples.
e is a random variable that accounts for differces in the original bulk densities of the f & n samples and for the effect of measurement error.
e has a mean of 0 and a variance, var(e), to be estimated
ef is the effect of the feller-buncher on bulk density. ef is a random variable with a mean [mean(ef)] and a variance [var(ef)], both of which are to be estimated. I assume mean(ef) is independendent of n and e. (That is, I assume higher bulk density soil is compacted as easily as lower bulk density soil.)

Mean(ef) is estimated by: mean(ef) = mean(f - n)

I estimated var(e) by: var(e) = 0.7 * var(a-b)
where a and b are paired 'before' samples located 10 feet apart. The '0.7' coefficient reflects my guess about the effect of the n and f samples being closer together than 10 feet.

I estimated var(ef) by: var(ef) = var(f-n) - var(e).

I assumed the ground the feller-buncher tracked had the same statistical distribution of bulk densities as found in the 'before' sampling. I assumed the effects of the feller-buncher were in a normal statistical distribution with mean(ef) and var(ef). I then estimated the statistical distribution (histogram) of bulk densities for the area tracked by the feller-buncher. In order to do this, I generated values by taking each 'before' bulk density value (308 values for each block) and adding a random value, drawn from a normal distribution with mean(ef) and var(ef). I did this addition using 20 different random values, for each 'before' value, to generate a total of 6160 values for each block. This statistical distribution indicated percent of soil compacted, for the area tracked by the feller-buncher. (This estimate was checked against the percentage of the 44 tracked samples that were compacted, and the two estimates agree very well.) I then subtracted the percent of soil compacted 'before' feller-buncher logging to find the increase in percent of soil compacted by the feller-buncher.

A similar procedure was used for the 'edge of skid trail' samples.

Results & Discussion

The results presented in the the text below is an average of the north and south blocks. Some of the results presented in tables and figures are for the individual blocks. When comparing numbers in the text with numbers in tables, this difference should be kept in mind to avoid confusion.

Undisturbed bulk density & Forest Plan standards

Eighty samples from areas that appeared to be undisturbed had an average bulk density of 0.881 Mg/m^3 and a standard deviation of 0.097 Mg/m^3 (Fig. 1). There was no difference between the north and south blocks. By FSM definition, non-ash soil is compacted if it has a bulk density 15% greater than the mean undisturbed soil. So the threshold for recognizing compacted soil is 1.013 Mg/m^3. Six of the 80 undisturbed samples had a bulk density higher than 1.013 Mg/m^3, so 7.5% of the soil was 'compacted' before disturbance. This apparent 'compaction' is due to natural variation in bulk density. The 7.5% value is higher than the 1% found by Sullivan (1989) on soil developed in volcanic ash. However, Geist and coworkers (1989) found standard deviations up to 10% of the mean on volcanic ash soils. In a soil where the standard deviation is 10% of the mean, 7% of the soil would be compacted by natural processes, assuming statistically normal distribution. Ash soil is derived from relatively uniform parent material, so other soils may be more variable.

The Forest Plan states as a standard "The total acreage of all detrimental soil conditions shall not exceed 20% of the total acreage within any activity area, including landings and system roads." Because 3.5% of the unit was in roads and landings, the standard was violated if 16.5% of the sampled area was compacted.

Impact of previous logging

On the two blocks, an average of 19% was compacted before this logging operation, with an increase in average bulk density of 0.034 Mg/m^3 (Table 1).

Table 1. Bulk densities before feller-buncher logging

Block	Mean Bulk Density	Area Compacted
	Mg/m^3	%
South	0.903	14.0
North	0.926	24.3

It is not intuitively clear how a small increase in bulk density (4%) can cause a large increase in the percent of an area compacted (11.5% = 19% - 7.5%). Geist and coworkers (1989) found similar results. They attributed this result to loosening effects, like displacement, partially counterbalancing compaction.

```
Relative Abundance,line count
    |                                    NNNN
    |                                    XXXX
    | UUUU = 'undisturbed' only          XXXX
    | NNNN = North block only    UUUU    XXXX
   | XXXX = both 'undisturbed'  UUUU    XXXX
    |       and North block      UUUUUUUUXXXX
    |                            UUUUUUUUXXXX
    |                            UUUUUUUUXXXX
  30|                            UUUUUUUUXXXX
    |                            UUUUUUUUXXXX
    |                            UUUUUUUUXXXX     c  Compacted
    |                            UUUUXXXXXXXX     c
    |                            UUUUXXXXXXXXNNNN c
    |                            UUUUXXXXXXXXNNNN c
    |                            UUUUXXXXXXXXNNNNNcNN
    |                            UUUUXXXXXXXXXXXXXcXX
    |                            XXXXXXXXXXXXXXXXXcXX
    |                            XXXXXXXXXXXXXXXXXcXX
  20|                            XXXXXXXXXXXXXXXXXcXX
    |                        UUUUXXXXXXXXXXXXXXXXXcXXNNNN
    |                        UUUUXXXXXXXXXXXXXXXXXcXXNNNN
    |                        UUUUXXXXXXXXXXXXXXXXXcXXNNNN
    |                        UUUUXXXXXXXXXXXXXXXXXcXXNNNN
    |                        UUUUXXXXXXXXXXXXXXXXXcXXNNNN
    |                        UUUUXXXXXXXXXXXXXXXXXcXXNNNN
    |                        UUUUXXXXXXXXXXXXXXXXXcXXNNNN
    |                        UUUUXXXXXXXXXXXXXXXXXcXXNNNN
    |                        UUUUXXXXXXXXXXXXXXXXXcXXNNNN
  10|                        XXXXXXXXXXXXXXXXXXXXXcXXNNNN
    |                    UUUUXXXXXXXXXXXXXXXXXXXXXcXXNNNN
    |                    UUUUXXXXXXXXXXXXXXXXXXXXXcXXNNNNNNNN
    |                    XXXXXXXXXXXXXXXXXXXXXXXXXcXXNNNNNNNN
    |                    XXXXXXXXXXXXXXXXXXXXXXXXXcXXNNNNNNNN
    |                    XXXXXXXXXXXXXXXXXXXXXXXXXcXXXXXXNNNN
    |                    XXXXXXXXXXXXXXXXXXXXXXXXXcXXXXXXNNNN
    |                    XXXXXXXXXXXXXXXXXXXXXXXXXcXXXXXXNNNN
    |                    XXXXXXXXXXXXXXXXXXXXXXXXXcXXXXXXXXXX
    |____________NNNNNNNNXXXXXXXXXXXXXXXXXXXXXXXXXcXXXXXXXXXXNNNNNNNNNNNNNNNN___
    |              |              |              |              |              |
   0.4            0.6            0.8            1.0            1.2           1.6
                                  Bulk Density, Mg/m^3
```

Fig. 1 Overlayed histograms for 'Undisturbed' samples and for samples from the North block. Histograms are scaled so that both include about the same area.   Each 'UUUU' and 'XXXX' stands for approximately 0.43 'Undisturbed' samples (n=80). Each 'NNNN' and 'XXXX' stands for approximately 1.66 North block samples (n=309). Observations to the right of the vertical lines of 'c's are compacted; observations to the left are not compacted.

There are two additional considerations that can help account for the large increase in the percent of the area compacted, despite the small increase in bulk density: (1) A small increase over a unit is probably due to a large increase on a small part of the unit. For instance, if 1/3 of the unit had been tracked, the increase on this 1/3 was 0.102 Mg/m^3 (three times 0.034). (2) As Figure 1 shows, there is much undisturbed soil that is not far below the 'compacted' density, and it takes only a small increase in bulk density (for instance, 0.102 Mg/m^3) to 'compact' this soil. Thus, most of the soil with bulk densities greater than 1.013 Mg/m^3 had not undergone a bulk density increase of 15%.

Impact of feller-buncher logging

The feller-buncher increased bulk density by 0.047 Mg/m^3 (Fig. 2, Table 2). This is a significant increase by Student's t-test. The increase is comparable to Zaborske's (1989) results of 0.056 Mg/m^3 and Floch's (1988) result of 0.046 Mg/m^3, and is less than McNeel & Ballard's (1992) result of 0.165 Mg/m^3. The feller-buncher compacted between 10 and 20 percent of the land it passed over (Fig. 2, Table 2). This is somewhat more than the area occupied by the grousers on the tracks. The edge of the skidtrail was compacted very little. The compaction that did occur on the edge of the skid trail was partially offset by deposition of low bulk density soil brushed from the skidtrail.

Table 2. Effect of feller-buncher track and "edge of skidtrail" surface conditions on soil bulk density.

Surface Condition	Increase in bulk density		Standard Deviation of Increase[b]	Increase in percent of area compacted[c]		
	mean	se[a]		mean-se[d]	mean	mean+se[d]
	-------	Mg/m^3	-------	---------	%	---------
Feller-buncher	0.047	0.019	0.065	10	15	20
Edge of skidtrail	0.002	0.031	0.081	-2	5	12

a. Standard error of the estimate of the mean.
b. Standard deviation is the square root of the variance, var(ef), which was
estimated as described in the Statistics section.
c. Total compaction is percent in this column plus the 'before' percents from Table 1.
d. Increases in percents calculated using the mean increase (column 1, this table) +/- the standard error of the increase (column 2, this Table).

The feller-buncher tracked 11% of the unit, in addition to the 18% disturbed by skidtrails and edge of skidtrails (Table 3). This contrasts with Zaborske's (1989) results of 7% impacted by feller-buncher alone and 47% impacted by skidders. Comparison of Table 1 with Table 3 indicates that this operation compacted about 6% of the unit, of which more than 4% is attributable to skidtrails and less than 2% is attributable to the feller-buncher. However Floch (1988) found that the area between tracks was somewhat compacted. So compaction due to the feller-buncher may be slightly greater than I estimated.

```
Relative Abundance,line count
    |                              NNN
    |                              NNN          NNN = non-tracked North Block
    |                              NNN          FFF = Feller-buncher tracked
    |                              NNN          XXX = Both NNN and FFF histogram
    |                              NNN
    |                           NNNNNN
    |                           NNNNNN   c
    |                           NNNNNN   c      Compacted
  30|                           NNNXXX   c
    |                           NNNXXX   c
    |                        NNNNNNNXXXFFFc
    |                        NNNNNNNXXXFFFc
    |                        NNNNNNXXXXXXc
    |                        NNNXXXXXXXXXc
    |                        NNNXXXXXXXXXcFF
    |                        NNNXXXXXXXXXcFF
    |                        NNNXXXXXXXXXcFF
    |                        NNNXXXXXXXXXcFF
  20|                        NNNXXXXXXXXXcXXNNN
    |                        NNNXXXXXXXXXcXXXXX
    |                        NNNXXXXXXXXXcXXXXX
    |                        XXXXXXXXXXXXcXXXXX
    |                        XXXXXXXXXXXXcXXXXX
    |                        XXXXXXXXXXXXcXXXXX
    |                        XXXXXXXXXXXXcXXXXXFFF
    |                     XXXXXXXXXXXXXXXcXXXXXFFF
    |                     XXXXXXXXXXXXXXXcXXXXXFFF
    |                     XXXXXXXXXXXXXXXcXXXXXFFF
  10|                     XXXXXXXXXXXXXXXcXXXXXFFF
    |                  FFFXXXXXXXXXXXXXXXcXXXXXFFF
    |                  XXXXXXXXXXXXXXXXXXcXXXXXFFFFFF
    |                  XXXXXXXXXXXXXXXXXXcXXXXXFFFFFF
    |               NNNXXXXXXXXXXXXXXXXXXcXXXXXFFFFFF
    |               NNNXXXXXXXXXXXXXXXXXXcXXXXXXXXFFF
    |               XXXXXXXXXXXXXXXXXXXXXcXXXXXXXXFFFFFF
    |               XXXXXXXXXXXXXXXXXXXXXcXXXXXXXXFFFFFF
    |            FFFXXXXXXXXXXXXXXXXXXXXXcXXXXXXXXFFFFFFFFF
    |_________XXXXXXXXXXXXXXXXXXXXXXXXXXXcXXXXXXXXXXXXXXXXXFFFNNN_______________
    |           |           |           |           |           |           |
   0.4         0.6         0.8         1.0         1.2         1.4         1.6
                                  Bulk Density, Mg/m^3
```

Fig. 2 Overlayed histograms for samples from the North block and for the calculated bulk density of the 11% of the unit tracked by the feller-buncher. Histograms are scaled so that both include about the same area. Each 'NNN' and 'XXX' stands for approximately 1.53 samples (n=309). Samples to the right of the vertical line of 'c's are compacted; samples to the left are not compacted.

Table 3. Effects of logging on area compacted.

condition	% of block in this condition	North Block: % of land in this condition compacted	North Block: % of block compacted[a]	South Block: % of land in this condition compacted	South Block: % of block compacted[a]
non-tracked	71	24[b]	17	14[b]	10
tracked by feller-buncher	11	39[c]	4	29[c]	3
skidtrail	8	70[d]	6	70[d]	6
edge of skidtrail	10	29[e]	3	19[e]	2
total	100	-	30	-	21

a. Percents in this column are derived by multiplying (% of block in this condition) times (% of land in this condition compacted).
b. Percent of 308 samples taken before feller-buncher logging that were compacted, from Table 1
c. Percent of 'non-tracked' land compacted plus the 15% from Table 2.
d. Assumed value (5 of 8 samples taken from skidtrails were compacted.)
e. Percent of 'non-tracked' land compacted plus the 5% from Table 2.

The 6% increase pushed the unit from about 19% compacted to about 25% compacted. Impacts from the feller-buncher are in addition to impacts from prior logging and from skidding. If the feller buncher had not been used, about 23.4% of the unit would have been compacted. If it had been realized before hand that the unit was in violation of standards, subsoiling would have been prescribed to rehabilitate the compacted soil.

Extrapolation to other operations

Impacts from the feller-buncher in this operation were small. However, that will not be the case for all operations. Factors that may give different results on other operations include:

1. Pattern of felling and skidding. If skid trails are closer than 120 feet, more area will be compacted by skidding. This factor probably accounts for the difference in results between this study and Zaborski's (1989) study.
2. The 'compactability' of the soil. I believe moist soil is more compactable than dry soil, and I recommend that feller-bunchers not be used on moist soil. Abundant woody debris on the forest floor probably reduces the pressure applied to the mineral soil and resulting compaction. Soil type influences compactability.
3. Number of trees cut by the feller-buncher. The more trees, the more area that will be tracked by the feller-buncher. I hypothesize the relationship is proportional (i.e. twice as many trees cut cause twice as much traffic).

4. Machine factors, such as ground pressure, total weight, track design, and vibration affect compaction in tracked soil. Maneuverabilty and reach of the boom may affect the amount of land tracked.

Acknowledgements
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Appendix
Miscellaneous Observations

1. The 'non-tracked' samples taken after logging had an average bulk density higher than samples taken before logging. It is unlikely that the feller buncher compacted soil at the 4 to 6 inch depth, 1 to 1.5 feet outside the track. More likely, the apparent increase is due to the fact that samples taken by two people after logging have a higher bulk density than samples taken by other people who sampled after logging. I adjusted the bulk density values for samples taken by those two people by a factor of 0.93.

This problem raises a question about whether measurement of bulk density with such short cores is an objective measurement. During sampling, soil is picked off both ends of the soil core, until the soil is 'level' with the ends of the core. Different people may see sligtly different configurations as 'level'. These differences may be significant with short cores.

2. One mitigation that I recommend on tractor units is that new skidtrails be located on old skidtrails, where practical. If compacted soil is compacted more, the percent of a unit compacted does not increase. However, this mitigation rests on the assumption that areas off of visible old skidtrails are less likely to be previously compacted than areas on visible old skidtrails. Data from this study indicate the limitations of this assumption: off of old skidtrails, 18% of the samples were compacted, and on the old skidtrails, only 26% of the samples were compacted. If this is typical, staying on old skidtrails may not be a very effective mitigation.

4. OVERLAND TRANSPORT DISTANCES OF SEDIMENT FROM ROADS,SWAMP PLANNING AREA

DRAFT DRAFT DRAFT DRAFT DRAFT DRAFT DRAFT

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2-12-99

SUMMARY

Sediment movment off roads was observed at 35 points. Under normal conditons, sediment was found no farther than 32 feet from road disturbance. I conclude that buffer widths of 50 feet or less are sufficient to protect streams from sediment from existing roads, except near scabs.

INTRODUCTION

Typically, water washes sediment off roads and carries it a certain distance before the water drops the sediment on the surface, either because the water infiltrates the ground, or because the water loses the power necessary to carry the sediment. One function of riparian buffer strips is to trap sediment before it degrades water quality. Perhaps Pacfish and Infish buffer widths were prescribed because the authors concluded "that non-channelized sediment flow rarely travels more than 300 feet and that 200-300 foot riparian 'filter strips' are generally effective at protecting streams from sediment from non-channelized flow" (Pacfish 1995, p.C-7). This statement is in line with Belt and coworkers' (1992, p.17) conclusion that "sediment flow through a buffer can travel up to 300 feet in a worst-case scenario". Similarly, ICBEMP (1997, p.328) displays a curve of sediment transport distance that will be used to calculate Riparian Conservation Area widths, if certain alternatives are adopted. This curve shows that in 10% of the cases sediment moves more than 200 feet on a 10% slope. The curve is based on Megahan & Ketcheson's (1996) results.

My observations are that sediment on the Malheur National Forest does not travel as far the ICBEMP curve, or Belt and coworkers' worst-case scenario, suggest. The purpose of this paper is to document systematic observations of sediment transport off roads on part of Long Creek/Bear Valley Ranger District.

METHODS

The Swamp Planning Area is part of Malheur National Forest, Oregon, in the upper Silvies River drainage above Logdell, approximately centered on T16S,R29E,sec. 10. It is about 33 square miles, with about 105 miles of open roads. Additional details about the area are given in the Discussion section, below.

Points on open roads in the Swamp planning area were randomly chosen; no consideration was given to whether or not the road had recently been used for log haul, the condition or position of the road, or any other factor except location of previous sampling points. I sampled thirty five points. I initially selected more points, but I rejected from sampling, points that were closer than 0.5 mile to an existing sampling point on the same road, because I thought such points would be similar. I went to each random point, and then I went down the road until I found a sag, outsloped surface, culvert, drain dip, water bar, or end of a ditch - places where water and sediment flowed off the road surface or inboard ditch. Observations were made in July, September, and October 1998.

I recorded the distance sediment appeared to travel beyond the road disturbance (the road prism or the lead-off ditch). I also recorded the distance at right angle to the road. Roads in Swamp planning area do not usually produce readily apparent sediment deposits, like those pictured by Ketcheson & Megahan (1996, cover and Fig. 2). This is probably because much less sediment is produced by existing Swamp planning area roads than by 1-4 year old Idaho Batholith roads. It was usually difficult to determine where sediment deposits stopped; deposits were usually thin coatings. Most of the sediment I observed probably had been produced in the last year or two; older sediment probably had plants covering it. I tried to err on the side of maximum sediment transport; I probably counted some bare spots caused by machinery or gophers as sediment deposits.

RESULTS

There were two places where sediment moves more than 100 feet off roads. At one place, a culvert discharges onto an abandoned road, which carrys water and sediment about 500 feet before it flows off the abandoned road, and the water infiltrates. At the other place, the road is on a "scab" (a non-forest area with shallow soils and limited ground cover). The scab supplies over-land runoff to the road, which concentrates the water, and discharges it near the edge of the scab. The water does not inflitrate, and it has eroded a rill 220 feet long. The rill delivers water and sediment to a scoured channel; the rill would have been longer if it had not entered the scoured channel. This rill suggests that Forest roads are not designed to handle over land runoff from scabs. Because these two places are atypical of the Swamp planning area, they were not used in the following analysis. So the following results do not apply where roads are near scabs, or where water flows onto another road.

Figure 1 shows the distance sediment travels at the other 33 observation points. The ninetieth percentile for sediment travel appears to be 50 feet or less. Except for the sediment deposit that was 65 feet long, almost none of the deposits were clearly visible, and lengths may be overestimated.

If one measures the distance from the edge of road disturbance to the end of the sediment, a different picture develops (Figure 2). The difference between Figure 1 and 2 is due to the fact that sediment does not travel directly away from the road; so, while sediment may have flowed 55 feet from the edge of the road, the distance from the road prism to the terminus of the "sediment deposit" is only 32 feet.

The distance from the center line from the road to the edge of the road disturbance can be large (Figure 3). The average is 25 feet. Some of the large distances were due to a wide County road prism (70, 45 feet). Other large distances were due to lead-off ditches (120, 54, 38 feet). Lead-off ditches add substantially to the width of road disturbance. When using GIS to find what roads may be putting sediment in streams, the distance from the center line to the edge of the road, and 1/2 the width of the stream, should be added to buffer widths.

```
  number of
observations
    |
    |
 15-|X
    |X
    |X
    |X
    |X
 10-|X
    |X
    |X
    |X
    |X
  5-|X
    |X
    |XX
    |XXX  X                   X
  1-|XXX_XX_______XXX__X_X____X________________________X____X_________X_________
     |         |         |         |         |         |         |         |
     0        10        20        30        40        50        60        70
             Distance sediment travels beyond road disturbance, feet
```

Figure 1. Histogram showing the number of observation points, where sediment appeared to travel the given distance beyond the edge of the disturbance from the road. Thus, for 15 observations, sediment appeared to travel 0 feet beyond the edge of the road disturbance, and for 1 observation, sediment travels 65 feet beyond the edge of the road disturbance. For many "0" observations, sediment stopped before it reaches the edge of the road disturbance. There were 33 observations. These data do not include two instances of transport greater than 100 feet, as described in the text.

```
number of observations
    |
    |X
    |X
 15-|X
    |X
    |X
    |X
    |X
 10-|X
    |X
    |X
    |X
    |X
  5-|X
    |X
    |XX
    |XXX XX
  1-|XXX_XX____X_XXX___X________X____X________________________________________
     |         |         |         |         |         |         |         |
     0        10        20        30        40        50        60        70
            Distance from road disturbance to end of "sediment deposit", feet
```

Figure 2. Histogram showing the number of observation points, for a given distance from the edge of road disturbance to the end of the "sediment deposit".

```
  number of
observations
    |
    |
  5-|
    |               XX
    |          XX   XX
    |          XX   XXX X
  1-|_________XXX_XXXXXXXXXX_XXXX_________X______X________X_______________X_/ /__X_
     |         |         |         |         |         |         |         |/ /   |
     0        10        20        30        40        50        60        70    120
         Distance from center line of road to edge of road disturbance, feet
```

Figure 3. Histogram showing the number of observation points that had the given distance, from the center line of the road to the edge of the road disturbance. There were 34 observations.

DISCUSSION

Sediment transport distances in the Swamp Planning Area are much less than reported by ICBEMP (1997) and Megahan & Ketcheson (1996) in the Silver Creek Study Area. Possible reasons for the difference include the following:

- Roads in the Swamp Planning Area produce much less sediment than those in the Silver Creek Study Area. Volume of sediment has more influence than any other variable on sediment travel distance (Megahan & Ketcheson 1996). Table 1 in Megahan & Ketcheson (1996) shows the average sediment volume from a culvert to be 19.7 yd^3, and the minimum to be 0.2 yd^3. Though I took no sediment volume measurements, I estimate only one of the observation sites in the Swamp Planning Area had a volume greater than 0.2 yd^3; most had volumes less than 0.1 yd^3. So probably roads in Silver Creek Study Area produced more than a hundred times as much sediment as roads in Swamp Planning Area. Possible reasons for the difference include the following:
  - Road Age. Roads in Silver Creek Study Area were 1-4 years old. 85% of the sediment produced by these roads was produced the first year after construction; another 8% was produced the second year (Ketcheson & Megahan 1996, Table 2). Roads in Swamp Planning Area are older (almost all more than 10 years old) and better vegetated; several had grass on most of the road surface.
  - Road Design. There are probably differences in road design and maintenance, due to differences in environment, budgets, professional judgement, and intended use. For instance, in Silver Creek Study area, 64% of the road drainage structures were culverts and 36% were rock drains; whereas in Swamp planning area, 22% are culverts, 17% are drain dips (rock drains?), 36% are sags or outslopes, 11% are waterbars, 11% are ditches that drain toward a stream or swale (without reaching it), and 3% are cattle guards. Culverts probably cause sediment to travel farther than rock drains (Megahan & Ketcheson 1996) and other drainage structures.
  - "Soils" on road prism. The decomposed granite in Silver Creek Study Area is more erodible than upland subsoils in Swamp Planning Area, derived from sedimentary and extrusive volcanic rocks. The decomposed granite is probably less fertile, so it may support less ground cover (but it may be moister, which may compensate for low fertility).
  - Topography. Swamp Planning Area is less mountainous than the Silver Creek Study Area. Roads are probably steeper in Silver Creek Study Area. There are probably more cut slopes to contribute run off and sediment to roads.
  - Climate. Total precipitation is about 35 inches at Silver Creek Study Area but is about 20-30 inches in Swamp Planning Area (Carlson 1974). Silver Creek Study Area is probably colder, which may inhibit the development of ground cover. Perhaps there is a difference in frequency of frozen ground.

- After water and sediment gets off the road prism, perhaps water infiltrates within a shorter distance in Swamp Planning Area. Possible reasons include the following:
  - Soils. The may be differences in infiltration rate, total water holding capacity, or other variables. Some of the topsoils in Swamp Planning Area are alluvium or volcanic ash.

- Topography. Slopes are generally steeper in Silver Creek Study Area, where the minimum slope is 9% and the average is 29% (Megahan & Ketcheson 1996, Table 1). At the observation point in Swamp Planning Area the minimum slope is 1% and the average is 9%.
- Climate. There is probably more run off from Silver Creek Study Area roads. Wet mantle conditions (when the soil will not absorb concentrated runoff) may be more common.
- Ground cover. Ground cover in Swamp Planning Area is often grass and elk sedge; perhaps ground cover in Silver Creek Study Area is less effective at dispersing small flows. But perhaps there is more woody obstruction below Silver Creek Study Area roads.

The width of buffer, between an activity and a stream, needed to protect streams from sediment depends on what the activity is. Road construction produces more sediment than any other forest managment activity; wider buffers are needed for this purpose. Sediment from existing roads used mostly for administrative and recreational purposes will rarely travel as far as 50 feet, as demonstrated by this study. Sediment from roads with active log haul and landings will probably travel farther than sediment in this study; two or three of the three roads that had sediment transport greater than 30 feet had log haul within the last 2-4 years.

But there are several indications that a buffer 50 feet wide (between the edge of a channel and the edge of a road) is sufficient to trap all significant sediment from roads, even under log haul (except on scabs):
- roads that had log haul within the last 4 years were sampled;
- Figure 2 indicates a 35 foot buffer is sufficient for normal conditions; 50 feet is probably sufficient even under log haul;
- a very small amount of sediment (probably less than 0.01 yd^{3}), reached 50 feet from the edge of the roads.

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5. Sediment Export from Logging Units during Summit Fire Salvage

DRAFT

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Introduction

In August and September 1996 the Summit wildfire burned on Malheur and Umatilla National Forests in the Blue Mountains of Eastern Oregon. The Supervisor of Malheur National Forest decided to log part of the area. During the planning for the timber sales, some people expressed a belief that ground based logging would cause sediment to enter streams. In response the Supervisor made certain decisions, including a decision to monitor sediment movement on uplands. The goal of this monitoring is to help determine if logging after wildfire is consistent with maintaining water quality. The objective is to roughly quantify the sediment that left some units.

Methods

Study Area & Treatments

In consultation with the Blue Mountains Natural Resource Institute, the Forest selected twelve units as "Monitoring Areas," to evaluate the long term impacts of salvage logging on such variables as down woody material, snags, plants, and soil disturbance. This sediment study was also done on these units. The units do not represent all the variation in the Summit timber sale area; the following factors were considered when the units were selected:

- Yarding was by skidding.
- Stands were intensively burned.
- Stands occupy warm-dry or hot-dry biophysical environments, with generally southern exposure (three blocks were dominated by ponderosa pine).
- Soils were mostly mapped as mapping unit 181. These are usually stony, clay loam to clay soils with moderate to high surface erosion hazard, moderate to high compaction hazard, and low displacement hazard; derived from Clarno breccia geology. But soils in units 323, 324, 418, 419, 421, 422, and 424 have substantial amounts of ash, at least

Table 1.

Unit	Block	Harvest	Harvest Dates Sep '98-Aug '99
323	1	Full	Feb-Apr, Aug
324	1	None	-
327	1	Partial	Feb-June
418	3	Partial	Oct-Nov
419	3	Full	Oct-Nov, Feb
420	3	None	-
421	2	Full	Dec-Feb
422	2	None	-
424	2	Partial	Dec-Jan
052	4	Full	Sep, Feb
520	4	None	-
522	4	Partial	Sep

along their lower boundaries.

These factors indicate there is a higher risk of sediment production from these units than most units in the Summit fire area.

The study has three treatments (full harvest, partial harvest, and no harvest) replicated on four blocks. The blocking factor is geographic proximity; maximum distance from one end to the other in a block is about 0.8 miles. Blocks were about 0.8 miles apart. Within a block, the three treatments were randomly assigned. Total acreage of the eight harvest units is 230 acres.

Harvest started in block 4 and progressed to block 1. Commercial removal from the full harvest units was less than expected. In order to meet other objectives of the study, the full harvest units were re-logged in February (units 419 and 052) or August (unit 323). Logs from the re-log were decked on the landings and left.

Sediment Fences

Sediment was measured using sediment fences installed after logging. In blocks 3 and 4 installation was in fall 1998; in blocks 1 and 2 installation was in summer 1999. At least 3 sediment fences were installed along the lower boundary of each harvest unit. (For unit 327, skidders crossed the lower boundary and decked logs on a road below part of the unit. The road was considered the lower boundary below the landing, not the actual boundary.) One fence was installed in each of the four no-harvest units. The lower boundary of the eight harvest units were examined, and each part of the boundary classified into one of three classes of expected sediment export: high, medium, or low. In blocks 3 & 4, while assigning a particular part of the boundary to a particular expected sediment export class, the following factors were subjectively considered:

- Is there a bare area that can contribute sediment? How large is it? How steep is it?
- Is there a water bar, rutting or other micro-topographic feature to concentrate water?
- If there is an undisturbed area between the bare area and the boundary: How wide is it? How much ground cover does it have? How steep is it?

Inspection of the lower boundaries in spring 1999 indicated that an additional factor is probably more important:

- Is overland flow crossing the boundary, exiting the unit?

For blocks 1 and 2, this additional factor was considered. The intent was to place one fence at the most likely position for sediment export from the unit (highest high risk), a second fence at the highest medium risk, and a third fence at a typical low risk position. Some units had no high risk positions, so fences were placed at the two highest medium risk positions. In units 323, 327, and 419 an additional high risk fence was installed.

Sediment fences were installed according to a method of Bob Brown of the Rocky Mountain Research Station, Moscow, Idaho. Briefly, sediment fences are installed as follows:

1. Layout is along 35 foot-long arc, with either end of the arc more-or-less on the contour, and the middle of the arc about 4 horizontal feet below the contour.
2. A 7" deep, 4" wide trench is dug along the arc.
3. Erosion control fabric is laid along the bottom of the trench, and on the uphill side.
4. Trench is refilled and soil compacted into the trench, securing fabric in place.

5. Stakes are driven into the ground about 7" down slope from where the fabric emerges from the soil, about 2-3 feet apart along the trench. The stakes should be deep enough that the stakes are firm and can hold the expected weight of snow, water, and sediment. If this cannot be done, rocks are piled around the stakes to provide additional support
6. Fabric is folded back on top of the filled trenches to the stakes, and stapled to stakes, with strips of tarpaper.

The collected sediment was dried (100 ^{o}C) and weighed. Weights were converted to volumes with a conversion factor of 0.9 g/cm^3 (56 lb/ft^3).

Results

Visual Inspection

There was an unusually heavy snowpack during the winter of 1998-9, providing ample opportunity for spring runoff. The lower boundary of the harvest units were inspected for signs of overland runoff exiting the units following snowmelt. Indicators of overland runoff are rearrangement or scour of litter or soil. Table 2 shows the results. The indicators are not always clear; on questionable areas, I made the best judgment I could. Also, during different conditions, such as more rapid snowmelt or an intense summer thunderstorm, overland runoff may have occurred at more points.

Table 2. Number of points where overland runoff exits the unit.

Unit	Dates inspected	Points without roads	Points influenced by roads
		----------- count	------------
323*	5-12-99	3	3
327	5-12-99	1	1
418*	5-12-99	1	0
419	6-10-99	0	14
421*	5-5-99	0	5
424	5-5-99	1	0
052*	5-24-99	4	2
522	5-24-99	1	3
	total	11	28

* See Appendix for remaining inspection work

There were two types of area that produced overland flow without roads. Seven of the 11 points without roads are ephemeral water courses that don't have enough scour to qualify as Pacfish Category 4 streams. These ephemeral "streams" are usually in draws, and/or are located at the head of Category 4 "streams". Six of the 11 points are below areas where very shallow, rocky soil produces surface runoff. (Three of the six are also ephemeral "streams".) To minimize sediment export, these two types of area should receive as little disturbance as possible during logging.

Units 323 and 052 have more points where overland flow exits because there is less ash soil, and more relatively shallow, rocky, clayey soil, than most units. Because of this soil, there is less infiltration and more overland runoff. These facts illustrate that this type of soil has higher risk of sediment export than other types. The low amount of infiltration below culverts in units 522 and 052 also support this conclusion (see below). This type of soil is probably not common Forest-wide.

In no case did runoff originating on skidtrails reach the boundary of a unit, except where skidtrails lead down to a road. Skidtrails did produce runoff and erode, but the water infiltrated before it reaches the unit boundary, except where the skidtrail connected to a road. The waterbar placement guideline was "Where skidtrails are liable to channel water, waterbars are placed at 10 to 20 feet vertical spacing." This spacing was sufficiently close to prevent highly concentrated runoff.

Where skid trails captured concentrated runoff from culverts or draws, often there was noticeable rilling. (See Sediment Fence section below.) Of the 11 points where overland runoff exited units without roads, six probably were affected by skidding, and the other five may have been. The small size of rills, and the amount of undisturbed ground that filters sediment, indicated that probably only a little sediment exited units, except for roads.

Roads are a larger source of sediment than upland logging, because of their bare, compacted surfaces (including running surfaces and cutslopes), concentration of runoff, and entry into Riparian Habitat Conservation Areas. This study only looked at sediment from roads in so far as roads affect sediment export from the units. Sediment export from the units from roads occurs at three types of places:

- where a road leaves a unit, and the ditch and running surface carry water off;
- where a road forms part of the lower boundary, and water runs off the side;
- and where culverts above the units concentrate surface runoff that does not infiltrate before it leaves the unit.

There were 28 points where overland runoff exited units on roads

Four of the 28 points are where culverts above the units concentrate surface runoff that does not infiltrate before it leaves the unit. (One of the four is in an ephemeral draw.) Three of these four are in units 052 and 522, which had shallow, rocky, clayey soil, and a road above the units to concentrate runoff from the relatively large area of shallow, rocky soil above the road. In May 1999 overland runoff from the three culverts could be traced for more than 1000 feet down hill. Again, this type of soil has higher risk of sediment export than other types, as mentioned above.

Thirteen of the 28 points were on an 1100 foot road segment that formed part of the lower boundary of unit 419. The road has shallow ruts, but is outsloped, so water ran off the road at frequent intervals. This road segment receives surface runoff from upslope because of the shallow, rocky soil which the road traverses. But because of the close spacing of the drains, the road concentrates runoff only a little.

Other places that water from roads exited the units include 5 points where a road exits the unit, 3 culverts, and 3 drain dips. A few observations confirm that roads probably produce more sediment than skidding. For instance, possibly the largest sediment source in the twelve units is a point where a road fords a category 4 "stream" that traverses unit 419. (The RHCA was excluded from the unit, so this ford is not actually in the unit.) As another instance, rills have formed below two of the three culverts, and one of these rill reaches a category 4 stream.

Sediment does not do any damage until it reaches streams. Probably most sediment that exited units did not reach streams; there was at least 100 feet between the unit boundary and the stream. Runoff at six of the 11 points without roads appeared to reach streams. Runoff from seven of the 28 points influenced by roads appears to reach streams. Roads are often further from streams than unit boundaries, and runoff from roads is not as often in ephemeral "streams" as it is from units. So a lower percentage of the runoff and sediment from roads enters streams than from units.

In summary, visual inspections indicate there probably is very limited sediment export from logging units, because water flows across the boundary at only a few points, and because little to no sediment transport is visible at these points, and because most sediment is deposited before it reaches a fish bearing stream. The points most likely to produce sediment are roads and ephemeral water courses.

Sediment Fences

There are several serious problems with the quantitative sediment measurements.

- Blocks 1 and 2 were logged in the winter, and the fences were not installed until the next summer, so the first spring runoff was missed.
- I overestimated the number of places that might export sediment, and put 21 fences at places where overland runoff did not occur, and only 10 fences at points where overland runoff did occur. Of the 10 fences that were installed where runoff occurred, two collapsed due to ponding of water in them.
- Dirt from sources other than erosion collected on the fences.
- Two fences were placed so as to catch sediment from landings, but the decks of logs placed by the non-commercial harvest stopped most sediment export from these landings.

Despite these problems, some suggestive data emerged.

There was probably little or no runoff during either summer. Probably all sediment production occurred during spring runoff.

"Sediment" was collected from 13 of the 21 fences where it appeared there was no overland runoff. This "sediment" was due to dirt placed on fences by tree planters, burrowing animals, and dry ravel of the side of the trench. During sediment collection, all material that could be clearly identified as being from these sources was discarded, but there was often a residual that could not be clearly identified. The maximum "sediment" collected from fences that lacked overland runoff was 0.009 cubic feet and the average (including zero collections) was 0.001 cubic feet. The 0.001 cubic feet figure can be used as a zero.

In addition to the sediment fences located on unit boundaries, there was one located on a skidtrail in unit 522, about 300 feet below a culvert. That fence caught 0.256 cubic feet of sediment the first year and 0.037 cubic feet the second year.

Although inconclusive because of the problems, these data suggest that appearances are qualitatively correct – that little sediment is being exported from units, and that roads are a larger sediment source than skidding. The largest amount of sediment, 0.691 cubic feet, was from a haul road that formed a small part of the lower boundary of unit 323 The second largest amount of sediment was 0.100 cubic feet captured in a draw in unit 424. It is unknown where this sediment came from; it could have come from skidding, or from other sources such as burrowing animals or the fire. The third largest amount of sediment was 0.098 cubic feet, in unit 327. At this location, the sediment probably came from a skidtrail in the bottom of a steep draw (25% slope) that captured an ephemeral stream for about 100 feet. The lower end of the skidtrail was about 100 feet above the sediment fence. Sediment exported from the other seven measured point was negligible, though in some cases the measurement may be misleading, due to such factors as sediment fence collapse.

	Table 3. Sediment collected in fences where there was overland runoff.			
Unit	Location	Sediment collected first year	Sediment collected 2nd year	comments
		ft^3	ft^3	
		Without roads		
327	Draw at head of category 4 stream	0.098		
418	Draw at head of category 4 stream	0.000	0.002	
424*	In draw bottom	0.100		
052	In draw bottom below landing	trace	trace	
		Influenced by roads		
323*	Below drain dip	0.691		
323*	Below drain dip, below landing	0.005		Sediment collected is less than if the logs had not been decked on the landing during the "re-log".
327*	Below drain dip, below landing	0.008		Part of sediment fence collapsed first winter, probably losing most sediment
421*	Below culvert	0.011		
421*	Road ditch	0.003		
522	700 feet below a culvert	0.009	unknown	Part of sediment fence collapsed, some sediment may have been lost. Overland runoff diverted away from this fence before second winter

* These sediment fences were installed in the summer, after winter logging. The main flush of sediment was not captured.

Quantitatively, appearances can be misleading. I was surprised at how much sediment was exported in the three largest cases, and how little was exported from the draw below the landing in unit 052, and down the ditch of the 045 road in unit 321.

Based on the visual observations and the sediment fence measurements, I made a "guesstimate" of the amount of sediment exported from each of the 39 points where overland runoff exited the harvest units. The sum of the "guesstimates" totaled of 4.6 cubic feet (Table 4). For the 13 points that appeared to be connected to streams, I assumed that all the sediment possibly reached a stream. With this assumption, 2.3 cubic feet, one half of the exported sediment, possibly reached streams These sums depend more on the "guesstimates" than on the measurements, and it could be wrong by a factor of 10, perhaps more. But, although the evidence is inconclusive, the "weight of the evidence" indicates only a small amount of sediment was exported from the harvest units.

Table 4. "Guesstimate" of sediment exported from units.			
	Without roads	Influenced by roads	total
		Exported from units	
Exported from units	11 points	28 points	39 points
Exported from units	0.6 ft^3	4.0 ft^3	4.6 ft^3
		Possibly introduced into streams	
	6 points	7 points	13 points
Introduced into streams	0.3 ft^3	2.0 ft^3	2.3 ft^3

Figure SC -1 - Alternative 2; Tractor Units and BAER Burn Severity

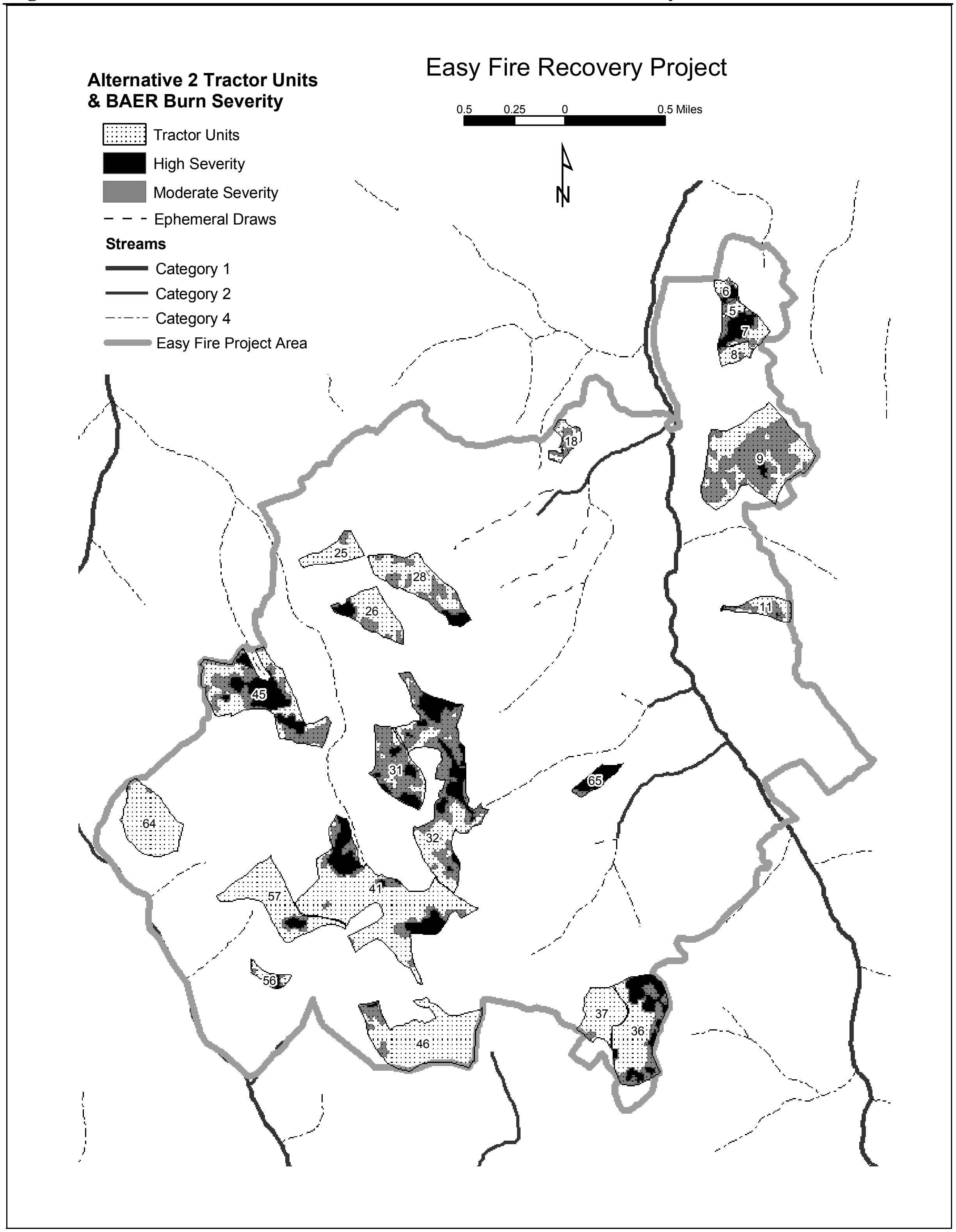

Figure SC- 2 - Alternative 3; Tractor Units and BAER Burn Severity

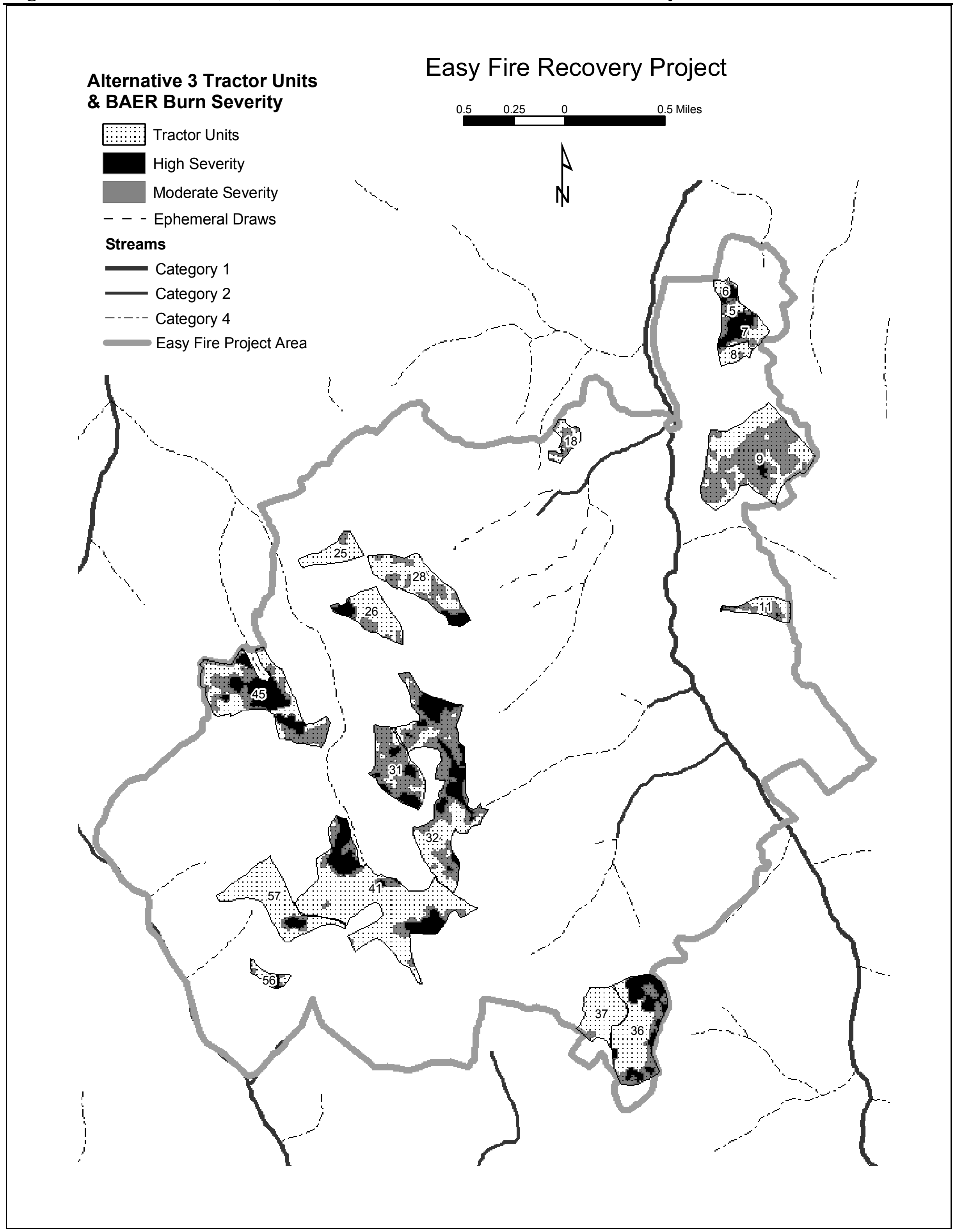

Figure SC - 3 - Alternative 4; Tractor Units and BAER Burn Severity

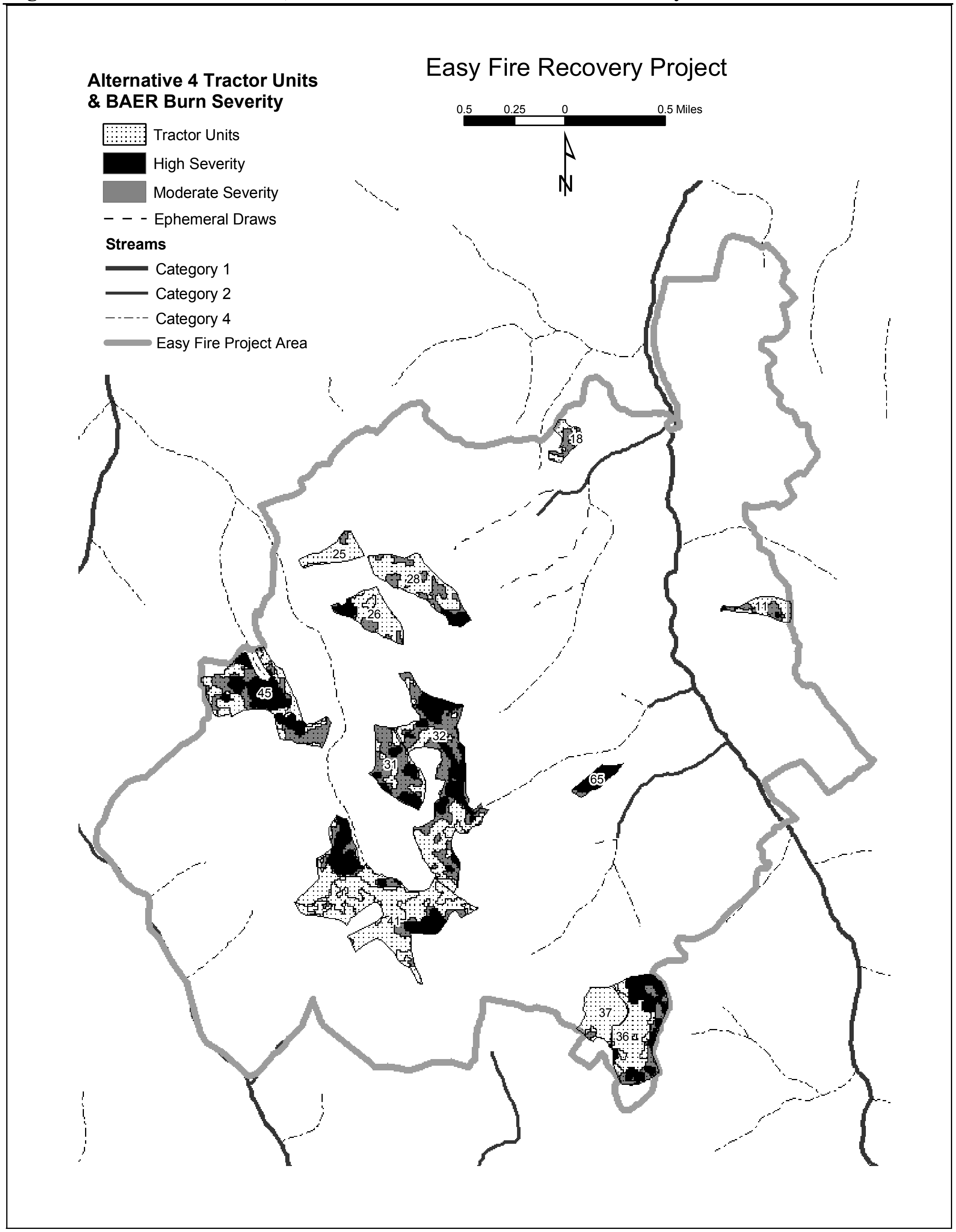

Figure SC - 4 - Alternative 5; Grapple Pile Units and BAER Burn Severity

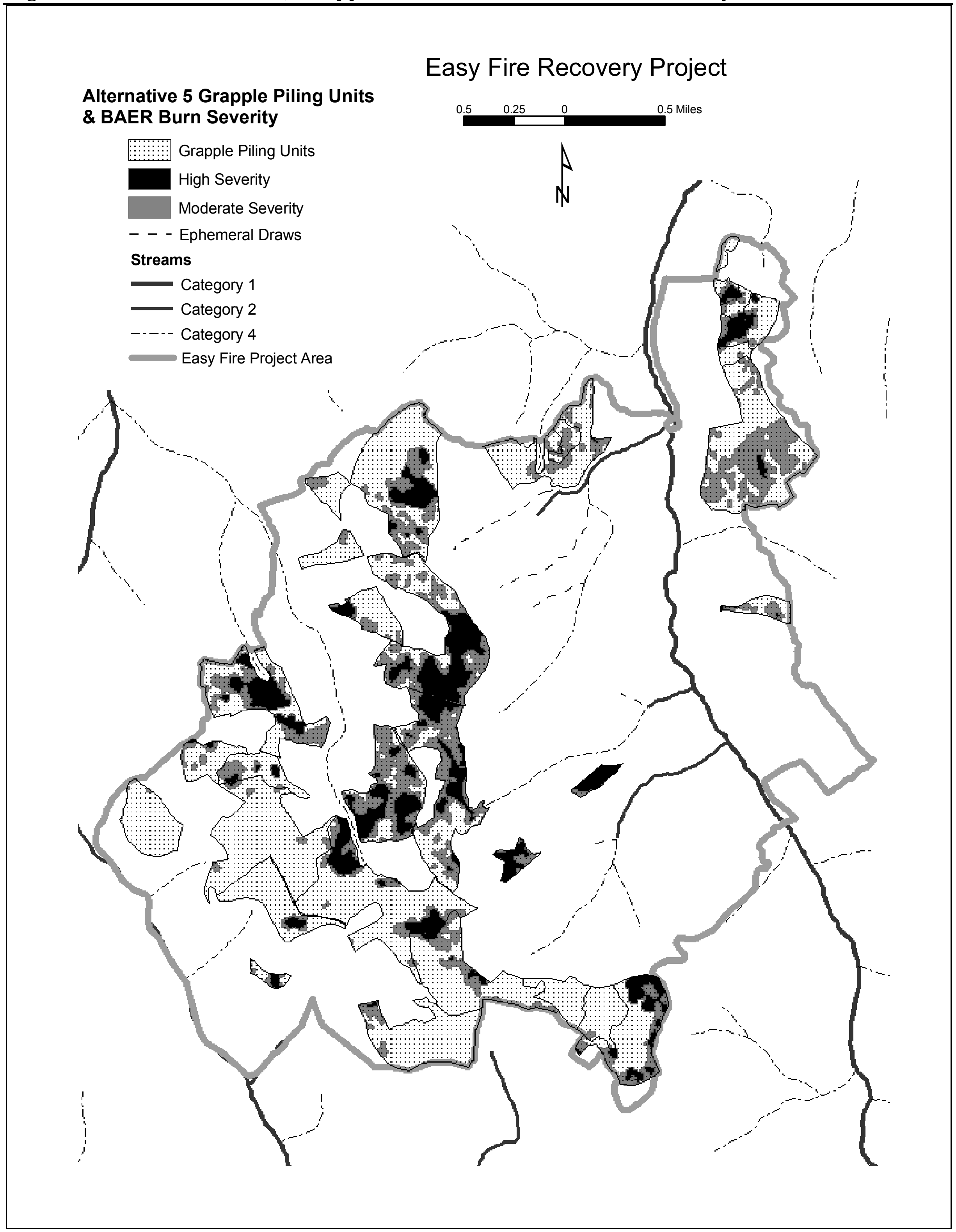

Figure SC - 5 – Perennial & Intermittent Streams, and Ephemeral Draws (labeled)

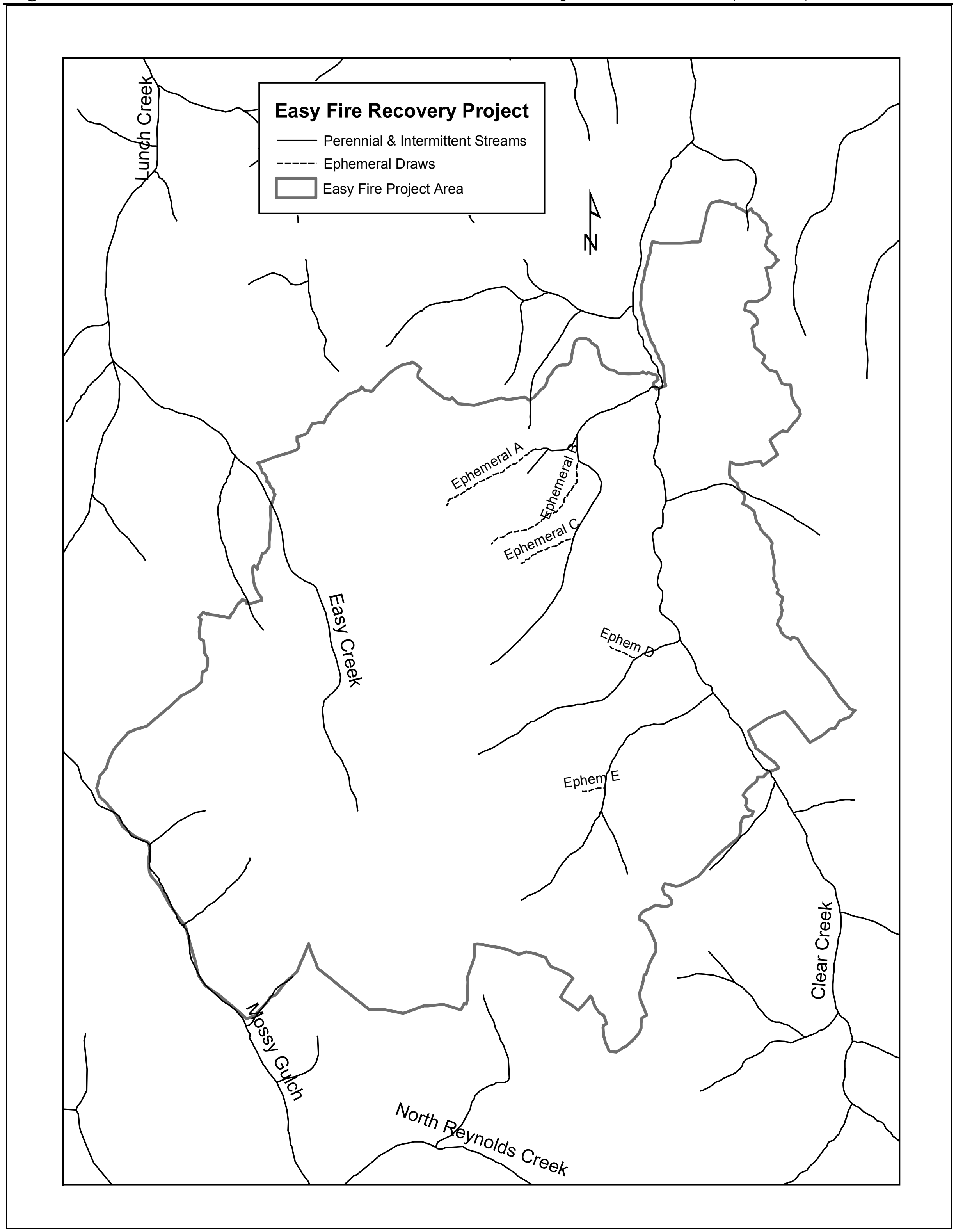

Table SC- 1: Easy Fire – Proposed Harvest Units & BAER Burn Severity Alternative 2 - Tractor Units

Unit - Alt. 2	Logging System	Unit Acres	Grapple Pile: yes/no	Main BAER Burn Severity	Low-Unburned BAER Acres	Moderate BAER Acres	High BAER Acres
5	Trac	6	-	L	3	1	2
6	Trac	7	-	L/H	2	2	3
7	Trac	20	-	L-H	6	4	10
8	Trac	8	-	H	0	1	7
9	Trac	114	Yes	L-M	54	57	3
11	Trac	15	Yes	L-M	9	5	1
18	Trac	11	-	L-M	6	5	0
25	Trac	17	-	L	16	1	0
26	Trac	30	Yes	L	22	4	4
28	Trac	48	Yes	L-M	30	14	4
31	Trac	43	-	L-H	9	24	10
32	Trac	117	-	L-H	40	45	32
36	Trac	70	-	L-H	37	11	22
37	Trac	30	-	L	29	1	0
41	Trac	153	Yes	L-H	113	14	26
45	Trac	89	Yes	L-H	33	25	31
46	Trac	83	-	L	76	6	1
56	Trac	7	Yes	L/H	4	1	2
57	Trac	52	-	L	47	2	3
64	Trac	49	-	L	49	0	0
65-T	Trac	10	-	H	0	1	9

Table SC- 2: Easy Fire – Proposed Harvest Units & BAER Burn Severity - Alternative 2 - Skyline & Helicopter Units

Unit - Alt. 2	Logging System	Unit Acres	Main BAER Burn Severity	Low-Unburned BAER Acres	Moderate BAER Acres	High BAER Acres
2	S	14	L	9	3	2
3	S	60	L-M	36	24	0
4	S	10	L-M	3	7	0
27	S	11	L	11	0	0
49	S	48	L-H	37	6	5
50	S	7	L	7	0	0
51	S	3	L-M	1	2	0
52	S	19	L	17	2	0
63	S	34	L-M	27	6	1
65-S	S	47	L-H	6	6	35
12	H	30	M-H	1	6	23
13	H	75	L-H	48	21	6
14	H	2	L-M	1	1	0
14A	H	3	L-M	1	2	0
15	H	85	L-M	57	25	3
20A	H	22	L-H	9	9	4
22	H	68	M-H	3	45	20
30	H	88	L-H	18	16	54
34	H	11	L-H	5	4	2
35	H	71	L-H	55	4	12
47	H	43	L-M	27	13	3
48	H	6	L	5	1	0
58	H	31	L	31	0	0
62	H	10	L	10	0	0

Table SC-3: Easy Fire – Proposed Harvest Units & BAER Burn Severity
Alternative 3 - Tractor Units

Unit - Alt. 3	Logging System	Unit Acres	Grapple Pile: yes/no	Main BAER Burn Severity	Low-Unburned BAER Acres	Moderate BAER Acres	High BAER Acres
5	Trac	6	-	L	3	1	2
6	Trac	7	-	L/H	3	1	3
7	Trac	20	-	L-H	6	4	10
8	Trac	8	-	L	7	1	0
9	Trac	114	Yes	L-M	54	57	3
11	Trac	15	Yes	L-M	9	5	1
18	Trac	11	-	L-M	6	5	0
25	Trac	17	-	L	16	1	0
26	Trac	30	Yes	L-H	22	4	4
28	Trac	48	Yes	L-H	30	14	4
31	Trac	43	-	L-H	9	24	10
32	Trac	117	-	L-H	40	45	32
36	Trac	70	-	L-H	37	11	22
37	Trac	30	-	L	29	1	0
41	Trac	153	Yes	L-H	112	14	27
45	Trac	89	Yes	L-H	33	25	31
56	Trac	7	Yes	L-H	4	1	2
57	Trac	52	-	L	47	2	3

Table SC - 4: Easy Fire – Proposed Harvest Units & BAER Burn Severity, Alternative 3 - Skyline & Helicopter Units

Unit - Alt. 3	Logging System	Unit Acres	Main BAER Burn Severity	Low-Unburned BAER Acres	Moderate BAER Acres	High BAER Acres
2	S	14	L-M	9	3	2
3	S	60	L-M	36	24	0
4	S	10	L-M	3	7	0
27	S	11	L	11	0	0
49	S	48	L-H	37	6	5
50	S	7	L	7	0	0
51	S	3	L-M	1	2	0
13	H	34	L-M	26	8	0
14	H	2	L-M	1	1	0
14A	H	3	L-M	1	2	0
15	H	85	L-M	57	25	3
20A	H	22	L-H	9	9	4
34	H	11	L-H	5	4	2
35	H	71	L-H	55	4	12
47	H	43	L-H	27	13	3
48	H	6	L	5	1	0
58	H	31	L	31	0	0

Table SC - 5: Easy Fire – Proposed Harvest Units & BAER Burn Severity, Alternative 4 - Tractor Units

Unit - Alt. 4	Logging System	Unit Acres	Grapple Pile: yes/no	Main BAER Burn Severity	Low-Unburned BAER Acres	Moderate BAER Acres	High BAER Acres
11	Trac	15	Yes	L-M	9	5	1
18	Trac	11	-	L-M	6	5	0
25	Trac	17	-	L	16	1	0
26	Trac	30	Yes	L-H	22	4	4
28	Trac	48	Yes	L-H	30	14	4
31	Trac	43	-	L-H	9	24	10
32	Trac	117	-	L-H	40	45	32
36	Trac	70	-	L-H	37	11	22
37	Trac	30	-	L	29	1	0
41	Trac	153	Yes	L-H	113	14	26
45	Trac	89	Yes	L-H	33	25	31
65-T	Trac	10	-	M-H	0	1	9

Table SC - 6: Easy Fire – Proposed Harvest Units & BAER Burn Severity, Alternative 4 - Skyline & Helicopter Units

Unit - Alt. 4	Logging System	Unit Acres	Main BAER Burn Severity	Low-Unburned BAER Acres	Moderate BAER Acres	High BAER Acres
27	S	11	L	11	0	0
65-S	S	47	L-H	6	5	36
14	H	2	L-M	1	1	0
14A	H	3	L-M	1	2	0
20A	H	22	L-H	9	9	4
22	H	68	M-H	3	45	20
30	H	88	L-H	18	16	54
34	H	11	L-H	5	4	2
35	H	71	L-H	55	4	12

Table SC - 7: Easy Fire – Proposed Fuels Treatment & BAER Burn Severity, Alternative 5 - Grapple Pile Units

Unit - Alt. 5	Logging System	Unit Acres	Grapple Pile	Main BAER Burn Severity	Low-Unburned BAER Acres	Moderate BAER Acres	High BAER Acres
1	none	5	Yes	L	5	0	0
5	none	9	Yes	L-H	5	2	2
6	none	7	Yes	L/H	3	1	3
7	none	32	Yes	L-H	16	5	11
8	none	9	Yes	L	8	1	0
9	none	158	Yes	L-M	88	67	3
11	none	15	Yes	L-M	9	5	1
18	none	11	Yes	L-M	6	5	0
19	none	75	Yes	L-M	61	14	0
23	none	139	Yes	L-H	89	27	23
24	none	15	Yes	L-M	12	3	0
25	none	17	Yes	L	16	1	0
26	none	31	Yes	L-H	22	5	4
28	none	134	Yes	L-H	42	40	52
31	none	90	Yes	L-H	18	39	33
32	none	116	Yes	L-H	40	44	32
33	none	13	Yes	M-H	0	3	10
36	none	78	Yes	L-H	40	15	23
37	none	30	Yes	L	29	1	0
39	none	27	Yes	L	27	0	0
40	none	97	Yes	L-M	74	18	5
41	none	153	Yes	L-H	112	14	27
42	none	131	Yes	L	125	5	1
43	none	30	Yes	L-H	20	6	4
44	none	27	Yes	L-M	22	4	1
45	none	99	Yes	L-H	47	23	29
46	none	83	Yes	L	76	6	1
56	none	8	Yes	L-H	5	1	2
57	none	52	Yes	L	47	2	3
64	none	49	Yes	L	49	0	0
65-T	none	10	Yes	H	0	1	9

Table SC - 8: Easy Fire – Fuels Treatment & BAER Burn Severity, Alternative 5 - Hand Felling, Piling & Burning Units

Unit - Alt. 5	Logging System	Unit Acres	Main BAER Burn Severity	Low-Unburned BAER Acres	Moderate BAER Acres	High BAER Acres
2	none	14	L-H	9	3	2
3	none	60	L-M	36	24	0
4	none	10	L-M	3	7	0
10	none	14	L-M	6	7	1
12	none	30	M-H	1	6	23
13	none	75	L-H	48	21	6
14	none	31	L-M	26	4	1
15	none	85	L-M	57	25	3
16	none	61	L-M	19	39	3
17	none	10	L-M	8	2	0
20	none	351	L-H	268	56	27
21	none	270	M-H	6	43	221
22	none	67	M-H	2	45	20
27	none	14	L	12	1	1
29	none	28	L	28	0	0
30	none	88	L-H	18	16	54
34	none	46	L-H	29	7	10
35	none	203	L-H	140	42	21
47	none	44	L-M	28	13	3
48	none	6	L	5	1	0
49	none	42	L-H	31	6	5
50	none	5	L	5	0	0
51	none	3	L-M	1	2	0
52	none	19	L	17	2	0
53	none	31	L-M	16	13	2
54	none	43	L-M	26	13	4
55	none	18	L	18	0	0
58	none	31	L	31	0	0
59	none	28	L	26	2	0
60	none	26	L	26	0	0
61	none	6	L-M	4	2	0
62	none	10	L	10	0	0
63	none	34	L-M	27	6	1
65-S	none	47	L-H	6	6	35
66	none	52	L-H	15	11	26